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AN EXPERIMENTAL K_a-BAND MIXER

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ABSTRACT

A K_a-band to X-band converter, using a Microwave Associates 1N53B crystal, has been developed and placed in operation at a field site. The crystal is mounted in a modified K_a-band crystal mount.

Several crystals were calibrated for field use. The measured parameters of bandwidth and conversion loss were 200 Mc and 12 to 15 db, respectively. A minimum detectable signal of -72 dbm was measured using an X-band traveling-wave tube as the first i-f amplifier.

PROBLEM STATUS

This is an interim report on one phase of the problem; work is continuing on this and other phases.

AUTHORIZATION

NRL Problem R02-34
Projects RUDC-4B-000/652-1 and
S031-01-00-231-2

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AN EXPERIMENTAL K_a-BAND MIXER

INTRODUCTION

This report describes an experimental K_a-band mixer that converts to X-band. The mixer is characterized by microwave intermediate frequency and wide bandwidth.

MIXER INPUT-OUTPUT SPECIFICATIONS

Mixers are nonlinear devices that combine a continuous local-oscillator input and a modulated r-f signal to produce an intermediate frequency output carrying the modulation of the r-f signal.

Specifications for this mixer were governed by the characteristics of the K_a-band transmitter and the X-band receiver with which the mixer had to be made compatible. A generalized mixer schematic is shown in Fig. 1. The frequency and bandwidth specifications are:

F_{is} = 34.80 Gc

F_{os} = 9.05 Gc

F_{lo} = 25.75 Gc

Bandwidth $\geq$ 200 Mc,

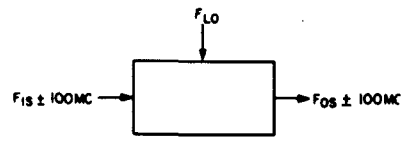

Fig. 1 - Schematic diagram for a mixer

where F_{is} = Input signal frequency

F_{os} = Output signal frequency

F_{lo} = Local Oscillator frequency.

The noise figure and conversion loss of a device meeting these specifications would be the limiting factors in the development of a practical unit. These two parameters depended, in part, on input signal level, local-oscillator coupling power loss, amount of available local-oscillator power, and input VSWR and output shunt capacitance of the device.

MIXER DEVELOPMENT AND ALIGNMENT

A QK463A klystron and a K_a-band signal generator were connected to a tunable K_a-band crystal holder with a 3-db directional coupler. The crystal holder was terminated in an X-band waveguide crystal detector. Attenuators, wavemeters, and current and power measuring devices were placed at appropriate places in the circuit. Figure 2 is a schematic of the test bench layout.

Measurements of K_a-band crystal current versus conversion loss and available local oscillator power were made after the appropriate input and local oscillator frequencies (F_{is} and F_{os}) were introduced into the system. The minimum conversion loss was approached when enough local oscillator power was available to produce a crystal current

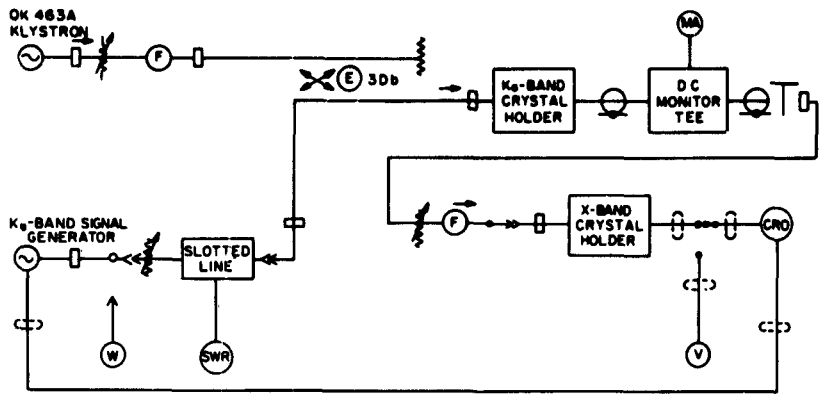

Fig. 2 - Initial mixer test bench setup

of 0.8 ma.* The minimum amount of available local oscillator power needed to produce this crystal current indicated a 15-db local-oscillator-to-crystal coupling. Maximum bandwidth and minimum conversion loss was obtained by varying the crystal insertion depth and positioning the crystal mount's movable short.

All of these preliminary measurements served as a basis for final component selection and alignment of the mixer.

The final basic mixer circuit was composed of a QK463A Raytheon Klystron connected through a 10-db directional coupler to a Microwave Associates 1N53B crystal. This crystal was placed in a Microwave Associates modified 513A crystal mount that terminated in a Microlab coaxial dc monitoring tee and a coaxial (2-10 GC) low-pass filter. Several other components were included for convenience of operation. These components were connected together as shown in Fig. 3.

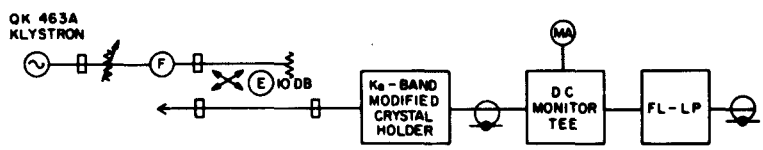

Fig. 3 - Final basic mixer schematic

The 1N53B crystal was the latest of the series available and had the smallest conversion loss. The 513A crystal mount had the smallest specified output shunt capacity (3×10^{-12} farads).

This crystal mount did not provide crystal insertion depth variation. Figure 4 is a picture of a unit that has been modified for this purpose. The crystal, with the collar loosely attached and firmly seated on the alignment pins, was inserted in the crystal holder to a particular depth and locked to the collar.

*R.V. Pound, "Microwave Mixers," Radiation Laboratory Series Vol. 16, Sec. 2.4, p. 56, New York:McGraw-Hill, 1948

Measurements of the conversion loss and bandwidth were made and are given in Table 1. An input signal power level of -15 dbm was used for these measurements. The bandwidth was taken to be the change in frequency associated with a 3-db increase in the conversion loss. This change in the conversion loss was measured with respect to the loss at the center output frequency.

Minimum conversion loss was obtained by adjusting the movable short and the crystal's insertion depth. The short was moved to its optimum position and locked in place with the crystal fully inserted in its holder. The optimum position of the crystal was then found by moving it in very small increments to peak the output power. Conversion loss measurements were made in 50-Mc steps. These measurements were then compared with the center frequency value to determine the 3-db variation points. Because of the differences in individual crystals, the crystal depth-insertion procedure had to be repeated at different output frequencies to obtain the best overall results from some of the crystals. Note that during this repeat step and also when a different crystal was being positioned, the short position was not changed.

A measurement of input power versus output power was made and is plotted in Fig. 5. This figure indicates the partial conversion linearity and dynamic range. No attempt was made to determine how long the unit could operate without crystal damage at the high power end or how much signal power could be tolerated.

NOISE FIGURE

The noise figure of the mixer could not be measured with the equipment that was available. The noise figure of the X-band traveling-wave tube used as the output amplifier is 10 db (100-Mc bandwidth). There were no discernable changes in the power output of the tube that could be attributed to the mixer noise output.

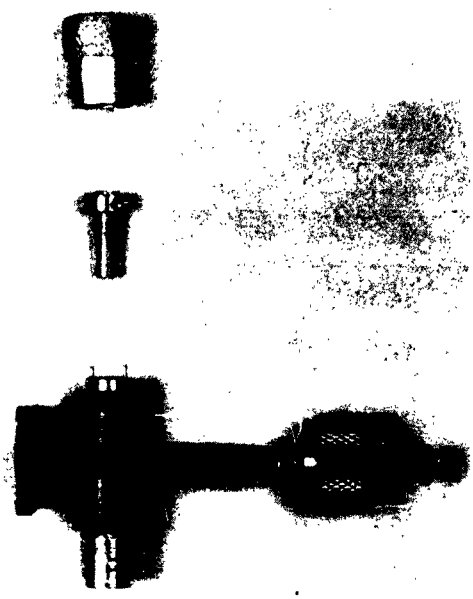

Fig. 4 - Modified crystal mount and crystal

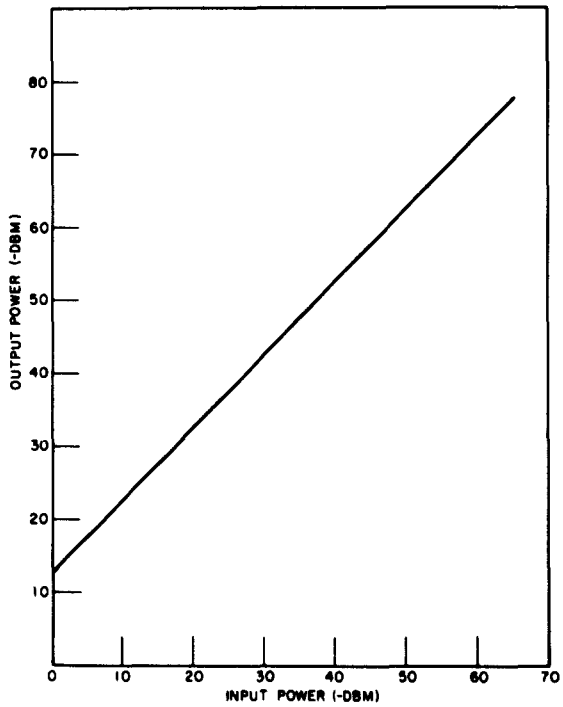

Fig. 5 - Mixer power conversion linearity

Table 1
Conversion Measurement Data

Input Frequency (Gc)	Output Frequency (Gc)	Crystals				
		A	B	C	D	E
Conversion Loss (db)						
34.665	8.90	12.50	11.80	13.60	13.70	12.40
34.715	8.95	13.60	14.60	14.40	14.50	13.80
34.765	9.00	13 70	17.00	14.10	14.20	14.40
34.815	9.05	12.70	16.80	12.20	12.20	13.70
34.865	9.10	11.90	16.50	12.60	11.70	11.10
34.915	9.15	12.50	15.10	14.60	14.30	10.10
34.965	9.20	17.30	15.50	19.30	19.40	15.90
Input Standing Wave Ratio						
34.665	--	1.43	1.80	1.74	1.40	1.66
34.715	--	1.36	1.85	1.74	1.35	1.75
34.765	--	1.29	1.95	1.75	1.24	1.80
34.815	--	1.13	2.00	1.60	1.14	1.80
34.865	--	1.18	1.90	1.43	1.19	1.60
34.915	--	1.32	1.65	1.44	1.36	1.50
34.965	--	1.35	1.70	1.55	1.37	1.60
Optimum Impedance Matching Frequency (Gc)						
--	--	9.00	8.95	9.00	9.00	8.975

A conclusion can still be drawn, however, for a receiver composed of the mixer and an output or intermediate frequency amplifier. Consider the standard overall receiver noise figure equation*

$$F_{rec} = F_{conv} + L\,(F_{if} - 1),$$

*G.C. Southworth, "Principles and Applications of Waveguide Transmission," New York: Van Nostrand, p. 657, 1950

where

F_{rec} = overall receiver noise figure ratio

F_{conv} = converter noise figure ratio

L = conversion loss ratio

F_{if} = i-f amplifier noise figure ratio

The conversion loss ratio for this mixer is relatively large and becomes the controlling noise figure factor. A receiver composed of a mixer, with a conversion loss on the order of 12 to 15 db, and an i-f amplifier will have an overall noise figure very nearly equal to the conversion loss in db plus the i-f amplifier noise figure in db.

A minimum detectable signal level check on crystal A was made and used to verify the conversion loss measurement. The minimum detectable signal level (limited in this case by the following TWT stage) was measured by introducing enough input signal power into the mixer to double the noise power output (-84 dbm for 100-Mc bandwidth) of the X-band traveling-wave tube. This power level was found to be approximately -72 dbm or, an input signal power level equal to the amplifier noise power plus the amount of power needed (12 db) to overcome the conversion loss.

CONCLUSIONS

A K_a-band to X-band frequency converter has been developed and has been used in an experimental field radar installation. It has the following characteristics:

F_{is} = 34.80 Gc

F_{lo} = 25.75 Gc

F_{os} = 9.05 Gc

Bandwidth = 200 Mc

Conversion loss = 12 to 15 db
Dynamic range ≥ 70 db
} Function of individual crystal

Power conversion ratio - linear over 70-db test range.

Eight randomly-picked 1N53B crystals were used in this development program. Data for five of these crystals are given in Table 1. Two of the crystals could not be used for lack of bandwidth and one was burned out. Figure 6 shows data on crystals A and D and illustrates the extremes of variation for the group of crystals.

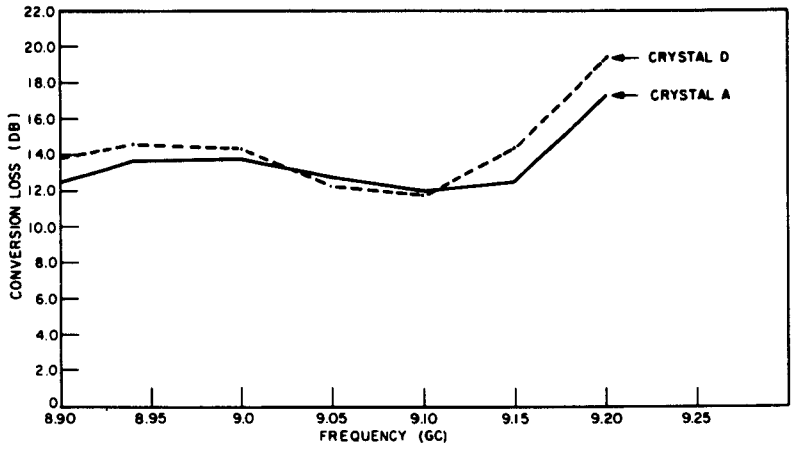

Fig. 6 - Crystal conversion loss

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3. Frequency translators – Dev.

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